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ABSTRACT

When two biological simulations on evolution and genetics (one originally developed for a conventional university undergraduate course) were introduced into Open University distance education classes, the difficulties encountered required a reappraisal of the concept of using computer simulation for distance learning and decisions on which simulation features were essential and which were merely desirable. The evolution course adapted a simulation called EVOLVE, which models the genetic and evolutionary consequences of two populations of a single flowering plant species coming together after a period of genetic isolation. The second simulation, WHEAT, models the inheritance of height in wheat for an experiment which biometrically analyzes the inheritance of a continuously varying character. To overcome problems of limited access to computer terminals and the need for cost-effective, interactive computing at remote sites, both a fully interactive and a non-interactive version of EVOLVE and a non-interactive but stochastic version of WHEAT were developed. Although the interactive element of computer assisted learning (CAL) was lost entirely in overcoming serious logistical problems, the resulting non-interactive programs have provided a tolerable compromise and, in the case of WHEAT, perhaps even a superior approach than if interactive terminals were used. Eight references are listed. (LMM)

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Computer Assisted Learning Research Group

Biological simulations in distance learning

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CAL Research Group Technical Report No. 12

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Biological simulations in distance learning

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ABSTRACT

Interactive computer simulations can be very effective educationally, but, at the present time, are not easily provided as part of a distance learning system. The problems of introducing biological simulations into two Open University courses and the proposed solutions are discussed in relation to sound CAL practise.

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Biological simulations in distance learning

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INTRODUCTION

Much experience and expertise has now been acquired, with "live" classes at both secondary and tertiary level, on the use of computer simulations in the teaching of biology [1 - 3]. This culminated, as far as the present author is concerned, in the development of an entire undergraduate practical course in genetics based very extensively on computer assisted learning (CAL) [4].

In this course an approach was developed in which a key feature was the interaction of individual, or small groups of, students with computer models of the systems they were studying. The idea was that students should attempt to answer increasingly more "open-ended" questions about the systems — questions which have been posed either by the tutor or, even better, the students themselves. Students arrived at answers by analysing output from programs, in each of which several parameters were left under user-control. It was important to leave as much initiative with the students as possible. This is in marked contrast to many laboratory-based exercises, in which all decisions relating to experimental design are taken in advance by the tutor because he/she dare not risk the time and/or expense of students adopting inappropriate or inefficient strategies. With computer simulation, "mistakes" can be made, detected and corrected within minutes. Answers quite often led to further questions and consequently several sessions at the computer terminal might be required to investigate a single

simulation thoroughly. Finally, results and conclusions were presented in the form of a written, and sometimes also verbal, scientific report.

It was perhaps natural to attempt to translate as many features as possible of this approach, which had proved so successful with coventional university classes, to the rather different distance learning environment of The Open University, whose students study part-time for their degrees through the use of correspondance texts, television, radio, audio-visual aids, summer and day schools and limited contact with part-time tutors. Difficulties were encountered, the magnitude of which became apparent only as the work progressed. In overcoming these difficulties it was necessary to re-appraise the whole concept of using computer simulation in distance learning and to decide which features of the approach outlined above were essential, and which merely desirable. This paper discusses some of the difficulties and how they were overcome, taking as examples two Open University courses which had rather different reasons for wanting to use CAL.

The Open University has had quite extensive experience in the use of computers for educational purposes [5], particularly tutorial CAL in a true distance learning mode and simulation CAL at summer school. However, comparatively little use has been made of simulation CAL by students working from home without the presence of Open University staff.

EVOLUTION (S364)

This course [6] is being offered for the first time in 1981. It was the original intention of the course team that the practical side of this third level joint Biology-Earth Science course be fulfilled by a 1-week residential summer school at a suitable venue. However, permission to

have a summer school was not granted and alternative provisions had to be made at relatively short notice. After consideration of the options available, it was decided that each student should carry out one of a number of biologically-orientated projects and report their work in the form of a Tutor-marked Assignment (TMA). It was, however, no trivial task to devise and developmentally test projects on topics such as speciation and natural selection, appropriate for unsupervised students living anywhere within the United Kingdom and which require not more than 10 - 12 hours study time. Not surprisingly, it was not known until shortly before the course was due to go out how wide the choice of projects would be during the first year of presentation.

One of the projects will be based on a computer simulation (EVOLVE) written specially for the course. EVOLVE models the genetic and evolutionary consequences of two populations of a single flowering plant species coming together after a period of genetic isolation. It is similar to a model developed for research purposes by Crosby [7]. Apart from the educational advantages which accrue from students interacting with simulations such as EVOLVE (which in fact highlights several important concepts in evolutionary theory), the course team was also influenced by the fact that development of this project could continue independent of biological seasons and that there was no danger of the relevant species being restricted to only certain regions of the United Kingdom, considerations which were imposing severe constraints on the development of other projects.

The author originally visualised an operation similar to that employed in the genetics course referred to above [3], with each student running EVOLVE on one of The Open University's computer terminals at a Study Centre. Each student would "discover" for himself/herself the basic

attributes of the system modelled and would then go on to investigate a single aspect of particular interest. It was realised, from previous experience, that it was unrealistic to expect students to go through both of these stages in a single visit to the terminal. This was true even of students who had some familiarity with computing and the use of simulations for educational purposes. For most students, however, this would be a relatively novel experience. On the other hand, it was also both unrealistic and unfair to expect students to make several visits to the terminal since many would have considerable distances to travel and would have problems in booking the University's very heavily used computer terminals. A further problem was that students would have to decide between the various projects at quite an early stage during the course. How could the relatively unconventional simulation project be judged with only a printed description for guidance?

GENETICS (S299)

This course [8] came into existence in 1976 with a 1-week summer school as an integral component. At summer school students performed various experiments on microbial and quantitative genetics, all but one of which required relatively sophisticated laboratory facilities. The exception was an experiment in which the inheritance of a continuously varying character, height in wheat, was analysed biometrically. Students spent some time measuring previously grown samples of wheat representing the six relevant generations and then considerably longer going through the fairly elaborate statistical analysis required to interpret the data. Considerable assistance was usually required at this stage from the tutors and demonstrators.

Due to rearrangements necessitated by the introduction of several new biology courses, S299 will lose its summer school from 1981. In partial replacement, an additional 4 hours of tutorial time is being provided. This time is being added to the existing 10 hours, which is being rearranged to provide the equivalent of two half-day schools — one in June/July on population genetics and the other in September on biometrical genetics. The schools will take place at two venues in each of the University's thirteen Regions and it is hoped that students will benefit considerably from assistance with what are generally reckoned to be the most demanding parts of a fairly demanding course. Although it was originally hoped to retain the "wheat experiment" for the biometrics school, it soon became clear that the cost of replicating the material for use in twenty-six widely dispersed venues almost simultaneously would be far too great. Moreover, given the amount of assistance students need with the statistical analysis, it would still be very difficult to do in the time available.

An obvious solution was to write a computer program (WHEAT) to model the inheritance of height in wheat and have small groups of students interacting with the program. There would be the added benefit that students would have to think about and specify the genetic crosses themselves, rather than be presented with previously grown plants.

However, appealing though it was, this proposed solution gave rise to a host of new problems. Few of the Open University's Study Centres have computer terminals in rooms suitable for the day schools as a whole. On the other hand, installing computer terminals and telephones in suitable rooms for half a day was much too costly to entertain. Microprocessors might seem to be the answer here — but for the fact that the University does not have sufficient suitable machines, which in any case would have

to be transported to the venues. With one or two terminals or microprocessors per group of about twenty students there would have to be some sort of circus arrangement with other relevant activities. Yet, a single tutor would be running each day school and it is known that students need a lot of assistance with the statistical treatment of such biometrical data. Finally, the people employed to tutor the course generally, and the day schools in particular, are appointed on their ability to teach the subject matter of the course. It would have been wrong to insist upon, or assume, that they were familiar with CAL as an educational technique or with the working of terminals or microprocessors (although, as it happens, some are indeed expert). Given all these difficulties, a different approach was clearly required.

SOLUTIONS

The problem, in the case of S364, was that students could not be expected to make multiple visits to Study Centres to run the program and, in the case of S299, it was the difficulty of providing cost-effective interactive computing at remote sites for short periods of time. The solution, in each case, appeared to fly in the face of sound CAL practise and, until recently, would not have been advocated by the author.

Two versions of EVOLVE were produced. One is fully interactive and is to be accessed through Study Centre terminals, and the other is non-interactive, having been designed to be run in the batch stream of the University's DECsystem-20 at Walton Hall.

The non-interactive version of EVOLVE is individually run for each student enrolled on the course for a standard 100 generations, with appropriate default settings for the various parameters. Because the program is stochastic, each run is unique. Nevertheless, the various, apparently quite different, outcomes can all be accounted for by the same evolutionary processes. Early in the academic year these printouts are mailed to the students, along with notes describing all the projects in detail. Students are therefore in a position to evaluate the various projects and to decide which one to do themselves. This decision has to be made as soon as possible, since several of the field investigations have to be underway by April. Thus, even students who opt not to do the simulation project will have had the chance to see, and think about the reasons for, the quite striking evolutionary changes apparent in the printout.

The simulation project is two staged — corresponding to the use of the mailed printout (Stage 1) and the interactive program (Stage 2). There are also two cycles of work for students who undertake the project.

In the first cycle of work, students are required to examine the printout, note the changes and, based on a synthesis of many concepts from S364 itself and the Science Foundation Course (S101), account for the changes in terms of natural selection theory (upon which the model is firmly based). They then prepare a <u>very</u> brief report of their conclusions and an outline of the investigation they propose to do using the interactive version of the program. This report is submitted to the tutors early in the summer. It is not assessed at this stage, but tutors advise students whether they are "on the right lines" in their interpretation of the Stage 1 printout and whether their proposed Stage 2 investigations are reasonable in terms of time, effort and intellectual content. These safeguards are very

important because the project TMA, being non-substitutable, is effectively a compulsory element of the continuous assessment component of the course. If a student acquired a totally wrong idea about the Stage 1 printout, it is rather unlikely that useful Stage 2 work would result. It would be unfair to have part of the project wholly dependant on getting something else correct. The tutor who advises a particular student after the first cycle of work, will also mark that student's submitted TMA and so can allow for assistance or advice given. It is also important that the student is well prepared for the one visit to the computer terminal and that the proposed investigation is not hopelessly ambitious for the time available. Again, having to tell the tutor in advance what is intended helps to optimise the students' limited time. Nevertheless, both students and tutors are advised that students should allow some time during the one 1-hour computer session in case unanticipated results need further investigation.

Students are permitted to use the interactive version of the program at Study Centres from 1st September onwards. This restriction was necessary because of the severe overloading of the computer facilities earlier in the academic year. However, it does serve the useful purpose of preventing students completing the TMA before studying the most relevant units in the course (Unit 10, Evolution by Natural Selection and Unit 11, Evolutionary Ecology). The full report on both Stage 1 and Stage 2 is then written up and submitted to tutors by the TMA cut-off date in late September. The tutors are asked to look for well summarised data and biologically sensible deductions from Stage 1 and evidence of a systematic approach in Stage 2, even if conclusions have to be tentative because of lack of time at the terminal. Students can submit only Stage 1 work if they desire, and still obtain a pass grade. However, good work in both stages is required for high grades. Because

it should be quite possible to grade students on the basis of their submitted work, they are not discouraged from co-operating at the interaction with the computer stage if they feel apprehensive about computers and computing.

It will not be known how many students have opted for the simulation project, rather than one of the others, until late 1981. Some monitoring of progress during the year will be possible through informal contact with part-time tutors, but most feedback will reach the course team at the time of the Examination Board meeting in November. Unless the exercise proves to be completely disastrous, the intention is that the project will be offered again in 1982 with such improvements as seem necessary. Meanwhile, other simulations will be developed which can be substituted in subsequent years.

For S299 an entirely non-interactive, but stochastic, version of WHEAT has been written. This program too is run in the batch stream at Walton Hall. Printout of sufficient runs is supplied to each biometrics day school tutor, who will distribute them, along with a specially written booklet, at the day school. The printouts come in two sections, each of which is identified with the same run number. The first sections, which are given to students, consist of data as might have been collected by measuring actual plants, although simple statistics (such as means and variances) are also given to save time. The second sections are retained by the tutors for use at the day school. Guided by the booklet and assisted, when necessary, by the tutor, students will process their own data sets with the ultimate object of calculating such parameters as broad and narrow sense heritabilities. The tutor is in an excellent position to help and to generally "trouble-shoot" because the second section of each printout has the detailed steps of each

individual analysis set out for rapid consultation. It is anticipated that the tutors will run group introductory and concluding sessions, with students working on their own,or in small groups, in between. While attendance at the day school is not compulsory and the work done there not directly assessed, there will be a TMA assessing this part of the course. There can be little doubt that day school attendees will be at an advantage.

In overcoming serious logistical problems, the interactive element of CAL has been lost entirely. This is more than offset by the much improved tutorial support afforded by the adopted scheme. As well as having the second sheet to "crib" from, the tutor can also ensure that all the runs used at a day school illustrate points which he/she wants emphasised or that a range of different systems (for instance, from total additivity to complete genetic dominance) are represented.

DISCUSSION

It can be seen that, because of a variety of difficulties, it is not always possible to transfer an approach to using computer simulation from the local to the distance learning environment without considerable modification. The changes sometime seem quite contrary to demonstrably sound CAL practise, particularly when the essentiality of interaction is called into question. However, the important point is whether learning is aided overall or not.

If several visits to the computer terminal could reasonably have been expected of S364 students, it might have been better to have required them to use only the interactive version of EVOLVE and "discover" for themselves even the basic features of the system modelled. However, how many would have decided not to "risk" trying something relatively

unknown and how many would have failed to see the fundamental point of the exercise without a tutor on hand to ask questions and proffer advice?

While the S364 solution might be regarded as tolerable compromise dictated by expediency, the S299 solution has resulted in an approach significantly better than would have been possible using interactive terminals (given the resources currently available to The Open University) and possibly an approach educationally superior to that of the original summer school exercise.

The moral seems to be that hard-won experience in certain contexts should not be allowed to prevent pragmatic new solutions in changing circumstances. This should be borne in mind as the time approaches when, as a "spin-off" from computer-based T.V. games, The Open University can assume that all homes are, or can easily be, equiped with computing power. Clearly this opens out a whole range of fresh possibilities for the use of simulations in distance learning.

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The work reported here would not have been possible without the co-operation and advice of other members of the S364 and S299 course teams and of The Open University's Student Computing Service.

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